# Evaluation of an Instrument Developed by Philip Morris to Measure Sidestream Smoke of Cigarettes

June 28, 1989

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United States Testing Company, Inc.

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# United States Testing Company, Inc.

**Chemical Division**

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EST. 1880


## REPORT OF TEST

Evaluation of an Instrument
Developed by Philip Morris
to Measure Sidestream Smoke of Cigarettes

June 28, 1989

*TEST REPORT NO.* 032717

*SIGNED FOR THE COMPANY*

*BY*

Boyd Fagan

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UNITED STATES TESTING COMPANY, INC.

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## I. PURPOSE

The purpose of this project was to observe the performance of an instrument developed to measure the relative quantity of smoke produced by static burning of cigarettes, and to evaluate the reliability of its measurements.

## II. INTRODUCTION - DISCUSSION AND SUMMARY

Philip Morris has expressed a need to develop a means of objectively and quantitatively measuring and comparing the sidestream smoke produced by various cigarettes. Sidestream smoke is defined herein as the smoke produced by static burning.

An instrument with this capability has been developed by Philip Morris personnel. The role of U.S. Testing was to assist in the development of a test program which would provide sufficient information to permit an independent evaluation of the performance of this instrument.

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A preliminary conference was held at the Philip Morris Operations Center on April 11, 1989. Present were Alan Schoffman and Boyd Fagan of U.S. Testing, and the following Philip Morris personnel: J.E. Wickham, W. Claflin, K. Cox, J. Whidby, B. Goodman, D. McRae and P. Gauvin.

As a result of this meeting and further discussions, it was agreed that the current test program would be based solely on objective tests, i.e., the quantitative measurements made by the instrument. The testing discussed in this report was carried out over the period of April 27 to June 8, 1989.

## III. INSTRUMENT AND OPERATING PRINCIPLE

The instrument developed for measuring sidestream smoke is built around a Filtrona Model 302 8 port smoking machine. An optical system using a helium-neon laser producing green light (545 nm) and a photodiode detector is positioned such that the incident laser light transverses the width of the smoking chamber above the cigarette ports 3 times, using mirrors. This provides a path length of 165 cm.

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This arrangement permits the measurement of the reduction of the light transmitted through the optical path resulting from the smoke produced by the static burning of cigarettes placed in each of the eight ports of the smoking machine.

Controls were applied to assure uniform and reproducible burning. A minimum draft was used so that a continuous sidestream was produced by each cigarette and that random drafts due to air convection in the room were minimized, without accelerating the normal static rate of burning. The draft was equivalent to that used in standard smoking machines to give normal deliveries. Another control employed was that all cigarettes were marked at 10 mm and 40 mm from the smoking ends, to assure optimum uniformity of packing and homogeneity of smoke produced port-to-port. This also provided a reasonable integration interval for collecting data. The specific methodology used to collect the data is described in detail in Appendix D.



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The primary operating principle of this system and premise for its application is that the reduction of the incident light intensity bears a direct linear relationship to the quantity of smoke in the optical path. This occurs due to absorption by gases (relatively minor) and primarily the scattering of light by the particulates which we perceive as "smoke". In brief, this instrument operates on the same principle as that of a spectrophotometer or nephelometer, which are widely-used, conventional analytical instruments. This could be considered a specialized version of such a laboratory tool.

A detailed description of the instrument design and physical operating principles prepared by D. McRae of Philip Morris is included in this report as Appendix A.

## IV. DESIGN OF TEST PROGRAM

The main objective of the test program was to demonstrate that the instrument under discussion can make measurements which reliably quantify the differences in the smoke produced by different cigarettes. Philip Morris elected to use Marlboro Lights 100's (ML-8) as the high level reference cigarette. Accordingly, the quantity of smoke produced by simultaneously burning 30 mm of 8 of these cigarettes was assigned a value of 100%. Measurements of all other cigarettes are then expressed relative to ML-8=100%.

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It is noted here that the actual physical measurements are made as % transmission (T) of the incident laser light through the optical path. This can also be expressed as "% attenuation", which is 100%-T.

The extinction coefficient is a mathematical function of the measured transmission and the optical path length. The derivation is decribed in Appendix A.

It is this factor that is directly linear with respect to the relative quantity of smoke, and the determining criterion of applicability of the instrument described here.

The overall system is calibrated by a series of neutral density optical filters (optical density is also a function of % T), and checked with each use. Each of the certified density values can be converted to an equivalent extinction coefficient, which can also be expressed as relative % smoke, on the basis of ML-8=100% for 8 ports. The use of these filters can minimize any potential errors or systematic biases due to instrument drift. A detailed discussion of the application of these filters with respect to this project is given in Appendix B.



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The test program itself was conceived as a 2 phase program. Phase 1 was a preliminary, or feasibility phase, which called for the acquisition of representative data from ML-8 plus several cigarettes of conventional diameter which produce lower levels of smoke. Quantitative feasibility (and linearity) was further demonstrated by comparing measurements from the analytical curve to the calculated theoretical value from a limited number of runs. These were discussed and reviewed during a meeting at Philip Morris on May 11, 1989. An interim summary report of this phase of the program was issued by memorandum during a follow-up visit by Boyd Fagan to Philip Morris for the purpose of determining the additional testing required to complete the program. This is included in this report as Appendix C.



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It was agreed that data would be obtained from the following:

A) ML-8 (sufficient data for good statistical evaluation as the primary reference point.)

B) Normal circumference cigarette (D9BI), which produces low side stream smoke.

C) An extra high smoke cigarette (G9GZ).

D) A "slim" cigarette (Capri).

E) An "ultraslim" cigarette.

F) Various combinations of ML-8 and D9BI
   1) 4 ports each
   2) 5 ports ML 8, 3 ports D9B5
   3) 2 ports ML-8, 6 ports D9BI
   4) 1 port ML-8, 7 ports D9BI

G) 6 ports only ML-8, other ports unlit cigarettes.

H) 4 ports only ML-8, other ports unlit cigarettes.

I) 2 ports only ML-8, other ports unlit cigarettes.

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## V. RESULTS

The test results are based upon a linear curve, the coordinates of which are % relative smoke (x-axis) and extinction coefficient (y-axis). The curve is derived from a single point representing the mean of extinction coefficients calculated from 23 measurements of ML-8, assigning a relative smoke value of 100% to ML-8. The curve is drawn through this point and the origin (0% smoke = 0 extinction). A secondary point is the calculation of % relative smoke of D9BI from the mean extinction coefficient from 16 measurements. This value is the basis of calculation of theoretical values for the various combinations of ML-8 and D9BI, which demonstrates the linearity and accuracy of the measuring system. Figure I shows the analytical curve, with the theoretical values of % smoke plotted against extinction coefficents derived from actual transmission measurements. Superimposed upon the curve are the individual neutral density filter extinction coefficients indicating their equivalents in % smoke relative to ML-8=100%.

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It is to be noted that all combinations of ML-8 and D9BI fell on or very close to the curve. The furthest point from the curve of this group (5 + 3) actually represents the mean of only 3 data points, and is within the uncertainty factor or experimental error, expressed as the standard deviation calculated as % relative smoke.

All cigarette test results are tabulated in Table I showing theoretical % smoke values compared with values obtained from the curve. It is to be noted that expected recovery ranges are given as a function of only one standard deviation. (3 x std. deviation is usually applied as the 95% confidence interval using 20 data points).

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FIGURE I QUANTITATIVE CALIBRATION CURVE

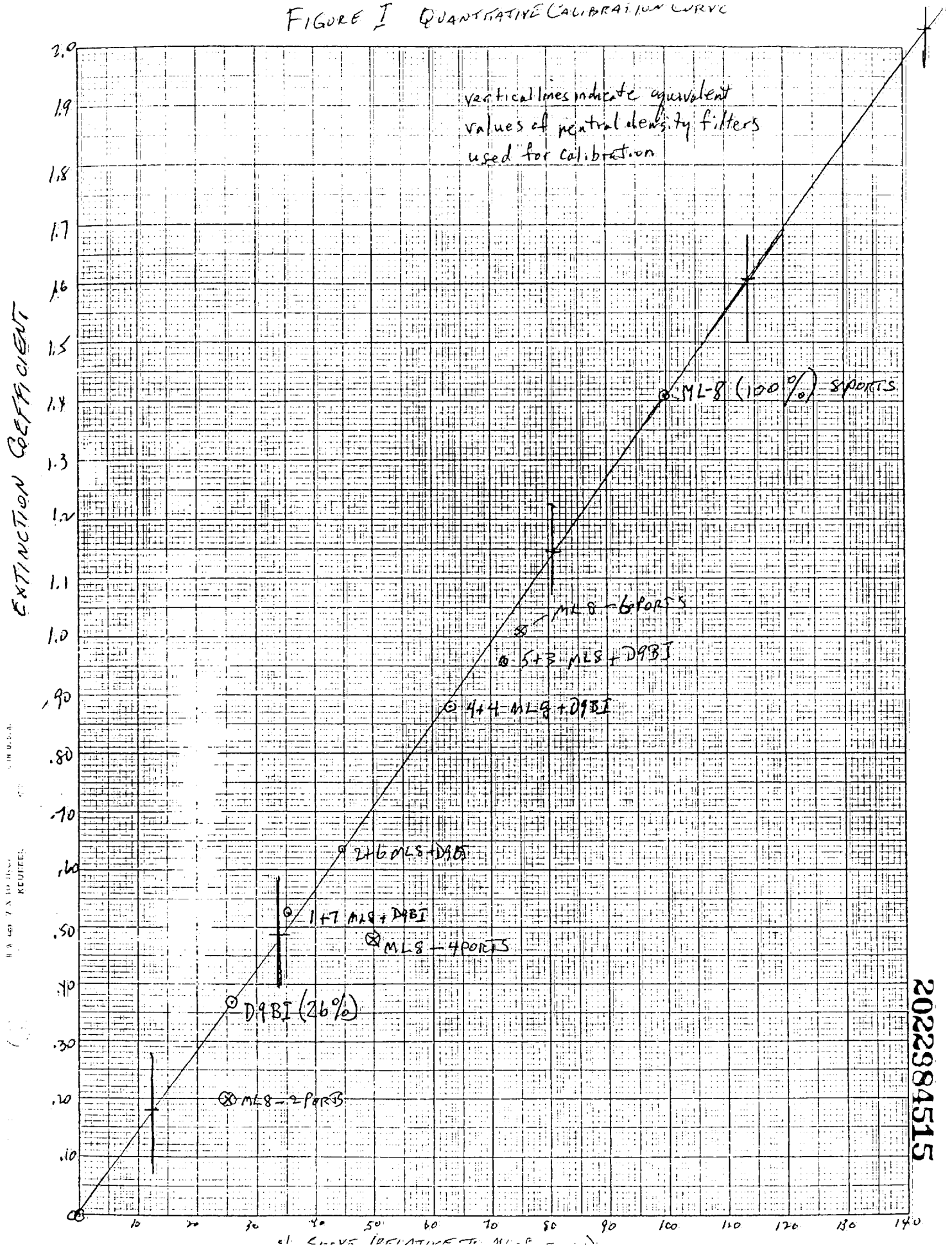


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Table I
Summary of Test Results

| A Sample | B Extinction Coefficient | C % Smoke Theoretical | D % Smoke Measured | E Std. Deviation % Smoke (+) | % Recovery (D/C) | Expected Recovery Range (100 + E) | # Data Points |
|---|---|---|---|---|---|---|---|
| ML-8 | 1.41 | 100 | 100 (ref) | 8 | 100 (ref) | 92-108 | 23 |
| D9BI | 0.37 | --- | 26 (ref) | 3.5 | --- | 87-113 | 16 |
| D9Z0 (Phase I) | 0.89 | --- | 63 | --- | --- | --- | 10 |
| ML8-D9BI 1 - 7 | 0.525 | 35.25 | 37 | --- | 105 | --- | 4 |
| ML8-D9BI 2 - 6 | 0.637 | 44.5 | 45 | --- | 101 | --- | 3 |
| ML8-D9BI 4 - 4 | 0.88 | 63 | 62.5 | 7 | 99 | 89-111 | 9 |
| ML8-D9BI 5 - 3 | 0.956 | 72.25 | 67.5 | --- | 93 | --- | 3 |
| ML-8 6 ports | 1.01 | 75 | 71.3 | --- | 95 | --- | 8 |
| ML-8 4 ports | 0.48 | 50 | 34 | --- | 68 | --- | 10 |
| ML-8 2 ports | 0.20 | 25 | 14 | --- | 56 | --- | 9 |
| Capri | 1.08 | --- | 76.5 | --- | --- | --- | 12 |
| G9GZ | 1.88 | --- | 133 | --- | --- | --- | 8 |
| Ultraslim | 0.38 | --- | 26.5 | 1.5 | --- | 94-106 | 6 |

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Table II
Neutral Density Filters

| Certified Density | Extinction Coefficient | % Smoke Equivalent |
|---|---|---|
| 0.90 | 2.04 | 145 |
| 0.70 | 1.61 | 114 |
| 0.50 | 1.14 | 81 |
| 0.21 | 0.49 | 34 |
| 0.08 | 0.17 | 12.5 |

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Standard deviation values are shown only in cases where sufficient data were obtained. It should be noted, however, that all cigarette measurements, where expected values could be determined, fell within calculated expected ranges at high and low smoke levels.

Table II shows the equivalent values in relative % smoke (ML8=100) of the calibration filters.

Low recovery values for measurements of ML-8 using 2 ports and 4 ports burning suggest strongly that a limitation of the instrumental system in its present form exists, and that it must be used with all 8 ports burning. These tests indicate that this is due to changes in the dispersal and convection of the smoke being generated by the burning cigarettes.

Reduction in smoke produced by the test cigarettes, relative to ML-8 can be determined as 100 minus the % smoke determined from the curve. On that basis, Capri would represent 100-76.5 or 23.5% reduction, and the Ultraslim would indicate 100-26.5, or 73.5% reduction, relative to Marlboro Lights 100's.



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From Table I, Ultraslim and Capri can be compared by subtracting the relative % smoke values and dividing by the % smoke from Capri. This result is $\frac{76.5 - 26.5}{76.5}$ = 65.3% reduction.

Figure II shows a curve generated by assigning 100% to the extinction coefficient for Capri. Projecting the Ultraslim extinction coefficient of 0.38 on this curve gives a value of 34.7% relative smoke. Ultraslim thus shows 100 - 34.7 = 65.3% reduction of sidestream smoke relative to Capri.

## VI. CONCLUSION:

An instrument has been developed by Philip Morris to measure sidestream smoke. On the basis of the experimental data obtained during the project, the instrument appears to produce results which are reliable and reproducible. Further refinements can be accomplished by obtaining additional data, but the instrument can now produce useful information with respect to the relative amounts of sidestream smoke produced by the static burning of cigarettes, provided that all eight smoking ports are used.



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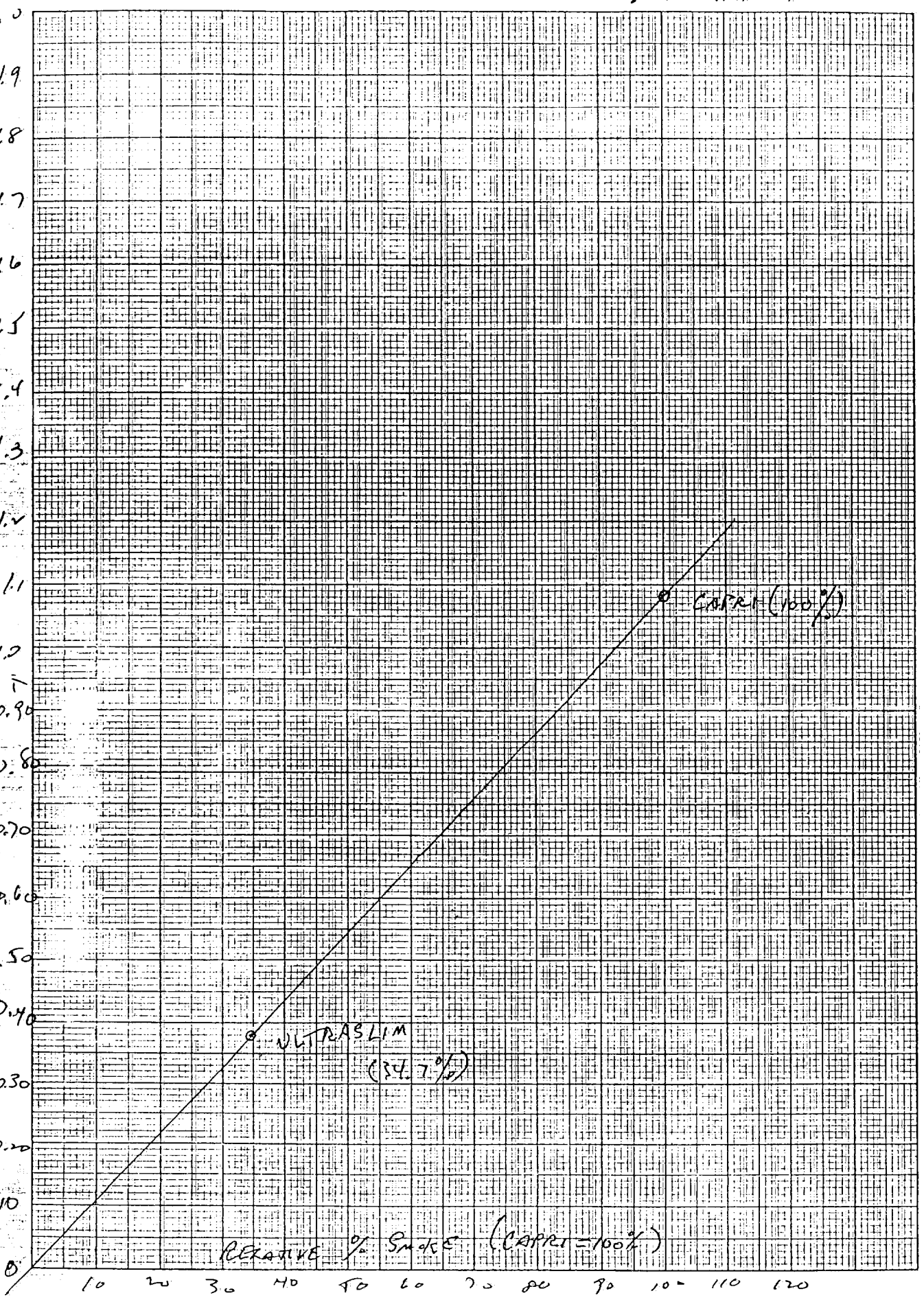
FIGURE II BASED on CAPRI VS ULTRASLIM

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APPENDIX A

## Instrument Design

A number of requirements were placed on the design of the sidestream monitor. First, the monitor had to be built around a full-function, commercially available smoking machine. Second, the smoking machine had to remain fully functional after all of the equipment to measure the sidestream smoke had been added to it. Third, the optical system also had to be built from commercially available components. Since the monitor was to be used for routine testing, it had to be easy to maintain and hard to break.

The smoking machine chosen for the monitor was the Filtrona 8-port machine, Model SM302 (Filtrona Instruments and Automation Ltd., Milton Keynes, England). This machine has 8 smoking ports arranged in a line and compactly spaced with a distance between ports of about 2.5 inches. The machine is a syringe-type machine set to pull 35 cc per puff. The puff interval and volume are adjustable. It also has an automatic lighting bar and string cutoffs on each port. The lighting bar was a very useful device. All of the ports could be lit simultaneously and reliably. The only modification of the machine was the replacement of the sleeve carriers which hold the filter assemblies with one made to hold disposable Cambridge filter pads. The cigarettes were held in place with molded silicon rubber holders rather than the traditional dental dams.

To collect the sidestream smoke we had to design a hood to enclose the smoking ports. The hood was made out of 1/4 inch Lexan™. The back piece of the hood had holes cut in it for the cigarette holders and the string cutoff anchor posts. The inside

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hood dimensions around the smoking ports was 10 cm deep by 55 cm across by 10.2 cm high. At the top of the smoking chamber the hood narrowed gradually down to inside dimensions of 2.5 cm deep by 55 cm wide. The total height of the hood was 61 cm. The front and the sides of the smoking chamber were hinged and could be flipped up to load and light the cigarettes. They were held open with magnetic catches and were held closed with pins inserted into catch holes.

The exhaust system for the hood was powered by a blower (Gast Mfg. Corp., Benton Harbor, MI). The flow rate was controlled with a valve and was measured with a rotameter. The rotameter was isolated from the flow system during the smoking runs in a bypass line to keep it from becoming contaminated by the smoke. The vacuum line from the blower was connected to a manifold. Nine 3/8 inch plastic tubes connected the manifold to the top of the hood. The purpose was to create a fairly even flow field across the hood.

The optical system built to measure the sidestream smoke was a simple transmission system. The light source was a green HeNe laser (PMS Electro-Optics, Boulder, CO.). This laser has a wavelength of 543.5 nm, close to the maximum sensitivity of the human eye at 555 nm. The laser also had the distinct advantage of producing a collimated beam of light without any other additional optics. Other light sources that were tried were a miniature xenon arc lamp and a quartz-halogen filament lamp. Both of these produce an intense white light that can be used to mimic sunlight.

The laser beam was passed three times across the upper part of the hood using mirrors before its intensity was measured by a

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silicon photodiode detector (Oriel Corp., Stratford, CT). The three passes were necessary to produce a path length long enough (165 cm) to obtain a transmission value of approximately 20% for control cigarettes. Windows were installed wherever the laser beam passed through the hood walls. The windows were microscope slide cover slips and were held in place with rubber cement. They could be quickly replaced after they became dirty from smoke deposition.

The transmission of the laser beam through the smoke was measured at 40 cm above the cigarettes. This distance was chosen to approximately match the filter position in the experimental CORESTA method for collecting sidestream for mass determinations. The hood and the optical system were mounted on a framework made from tubular optical benches (Oriel Corp.). These benches provided a large degree of flexibility in assembling the monitor.

The photodiode signal was converted into a 0 to 50 mV signal by the readout unit (Oriel Corp.). The readout unit included an LED digital meter. The readout unit had a sensitivity attenuator so that any arbitrary light level could be displayed as 1.000 allowing direct transmission measurements. A strip chart recorder was connected to the readout unit so that a hardcopy of each smoking run was made. In addition, a PC computer was used to collect and process the signal. The computer was equipped with a Data Translation board (Data Translation, Inc., Marlboro, MA) and LabTech Notebook (Laboratory Technologies, Corp., Wilmington, MA). Voltage levels were recorded at a rate of 4 every second. A program was written to start and end the runs, and to collect and process the data. The computer system and program were assembled

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by Randy Greene in the Computer Applications Division.

The delivery of cigarettes smoked in the monitor had to be checked. The flow of air through the hood had to be great enough to capture all of the sidestream smoke. Yet, it could not be so great as to adversely affect the burning of the cigarettes. To set the flow rate, standard test cigarettes with a known delivery were smoked under dynamic conditions. The flow rate was adjusted until the TPM of the test cigarettes matched the expected value. This flow rate was 96 l/min.

**Operation of Monitor**

The cigarettes to be tested in the monitor were marked at 15 and 45 mm from the lighting end and at 9 mm from the butt end. Eight cigarettes were inserted in the smoking ports to the 9 mm mark. The flow rate of the hood was adjusted if necessary. The cigarettes were then lit with the lighting bar on the smoking machine. Only a lighting puff was taken; the machine was turned off after the lighting puff. The sides and front of the hood were closed and computer data collection was started when the charline reached the 15 mm mark. The data collection was halted when the 45 mm mark was reached and the results were printed out.

**Theory**

Smoke is visible because light is scattered to the eye by the smoke particles. Thus, one might argue that any instrument designed to produce a measure of sidestream smoke visibility should measure the scattered light rather than the transmitted light. However, measuring scattered light is considerably more difficult than measuring transmission. It is nearly impossible to integrate

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the light scattered over all angles. Also, the amount of light scattered at any one angle is determined in a complex manner by the size distribution, number of particles and their refractive index. With a scattering measurement, when there is no smoke there is no signal detected. One is not able to compare the scattered light intensity to an intensity value without the smoke which would serve as an internal standard to correct for detector gain and optical loses. Absolute intensity measurements are notoriously difficult.

Transmission measurements are simple by comparison. There is no angular dependence of the signal. There is always the internal calibration point of the initial intensity when no smoke is present. The amount of light transmitted through an aerosol follows the equation:

$$I = I_0 \exp( -lb_{ext} ), \qquad [1]$$

where I and $I_0$ are the intensities of light with and without the smoke being present, l is the length of the light path and $b_{ext}$ is the extinction coefficient of the aerosol which is directly proportional to amount of smoke present. The extinction coefficient is the sum of the scattering coefficient, $b_{scat}$, and the absorption coefficient, $b_{abs}$. For cigarette smoke the absorption coefficient is small and can be neglected. This is shown by the refractive index of cigarette smoke. The real part of the refractive index, which in part determines the scattering behavior of the smoke, is approximately 1.52 at 514.5 nm[1]. The imaginary part of the refractive index, which determines the absorption

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behavior of the smoke, has been reported as 0.00133 at 514.5 $nm^2$.

The sidestream monitor measures the amount of light transmitted through the smoke aerosol. Equation 1 shows that if the amount of smoke is doubled the light transmitted through the smoke does not decrease by a factor of two. In order to determine some measure of the amount of smoke present one has to calculate $lb_{ext}$ using the equation:

$$lb_{ext} = - \ln ( I/I_0 ). \qquad [2]$$

To calculate the percent reduction in smoke from an experimental cigarette relative to a standard, one would use the equation:

$$\% \text{ Reduction} = 100 \times \frac{(lb_{ext})_{std} - (lb_{ext})_{exp}}{(lb_{ext})_{std}}. \qquad [3]$$

Note that the path length is a constant and cancels out.


1. D. D. McRae, J. Colloid Interface Sci. 87, 117 (1982).
2. M. Kerker, M. J. Scully, W. A. Farone and A. J. Kassman, Appl. Opt. 17, 3030 (1978).


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APPENDIX B

PHILIP MORRIS U.S.A.

I N T E R O F F I C E  C O R R E S P O N D E N C E

Richmond, Virginia

To: Warren Claflin Date: May 18, 1989

From: Douglas D. McRae

Subject: 8-Port Sidestream Monitor Calibration.

I have checked the operation of the 8-port sidestream monitor with a series of calibrated neutral density filters purchased from Oriel Corp. (Stratford, CT). The filters are specified in terms of their optical density. Optical density is defined as:

$$O.D. = \log_{10}(1/T),$$

where T is the fraction of light transmitted through the filter. The neutral density filter calibrations at 550 nm were used for calculating the expected transmission values. Before the calibration check was performed the zero and full scale positions were adjusted on the strip chart recorder. Three runs were made for each of the transmission values listed in Table 1. The measured transmissions from both the strip chart recorder and the computer data acquisition system are shown in Table 2. The data from the strip chart recorder were determined to the nearest 0.5%. The normal operating procedure was followed for each run with the full scale photodiode reading being adjusted to between 0.998 and 1.003 each time.

TABLE 1

| Expected % Transmission | Filter(s) (Optical Density) |
|---|---|
| 0 | Shutter closed |
| 0.9 | 2.03[1] |
| 12.6 | 0.90 |
| 20.0 | 0.70 |
| 31.6 | 0.50 |
| 51.3 | 0.29[2] |
| 61.7 | 0.21 |
| 83.2 | 0.08 |
| 100.0 | Shutter open, no filters |

[1]Combination of two filters with 1.13 and 0.90 densities.
[2]Combination of two filters with 0.21 and 0.08 densities.

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TABLE 2

| Run | Expected % Transmission | Measured % Transmission (Computer) | Measured % Transmission (Strip Chart) |
|---|---|---|---|
| 1 | 0.0 | - | 0.0 |
| 2 | 0.0 | - | 0.0 |
| 3 | 0.0 | 0.3 | 0.0 |
| 4 | 100.0 | 104.7 | 100.0 |
| 5 | 100.0 | 100.7 | 100.0 |
| 6 | 100.0 | 100.9 | 100.0 |
| 7 | 83.2 | 83.7 | 84.0 |
| 8 | 83.2 | 85.1 | 84.0 |
| 9 | 83.2 | 85.0 | 84.0 |
| 10 | 61.7 | 64.1 | 61.5 |
| 11 | 61.7 | 61.0 | 61.5 |
| 12 | 61.7 | 63.6 | 61.0 |
| 13 | 51.3 | 52.6 | 52.0 |
| 14 | 51.3 | 52.0 | 52.0 |
| 15 | 51.3 | 51.7 | 52.0 |
| 16 | 31.6 | 33.7 | 32.0 |
| 17 | 31.6 | 32.6 | 32.0 |
| 18 | 31.6 | 32.6 | 32.0 |
| 19 | 20.0 | 20.4 | 20.0 |
| 20 | 20.0 | 20.4 | 20.0 |
| 21 | 20.0 | 19.4 | 20.0 |
| 22 | 12.6 | 13.4 | 13.0 |
| 23 | 12.6 | 11.9 | 13.0 |
| 24 | 12.6 | 12.5 | 13.0 |
| 25 | 0.9 | 0.5 | 1.0 |
| 26 | 0.9 | 0.2 | 1.0 |
| 27 | 0.9 | 0.2 | 1.0 |

A plot of the computer determined data vs the expected values is shown in Figure 1 along with the regression line. Likewise, Figure 2 shows a plot of the strip chart values vs the expected values and the regression line. Information on both regressions are listed with their respective figures.

The figures show excellent agreement between the expected and measured transmission values. Both show R squared values of 99.9%.

As requested by U.S. Testing, the experimental data is also shown in Table 3 in terms of the extinction coefficient, defined here as:

$$\text{Ext. Coef.} = -\ln(T).$$

This table shows that significant differences between the expected and measured values can occur when the amount of light transmitted through the system becomes close to zero (a very dense smoke). This is due to the nature of the natural logarithm function.

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TABLE 3

| Run | Expected Ext. Coef. | Measured Ext. Coef. (Computer) | Measured Ext. Coef. (Strip Chart) |
|---|---|---|---|
| 1 | - | - | - |
| 2 | - | - | - |
| 3 | - | 5.73 | - |
| 4 | 0.00 | -0.05 | 0.00 |
| 5 | 0.00 | -0.01 | 0.00 |
| 6 | 0.00 | -0.01 | 0.00 |
| 7 | 0.18 | 0.18 | 0.17 |
| 8 | 0.18 | 0.16 | 0.17 |
| 9 | 0.18 | 0.16 | 0.17 |
| 10 | 0.48 | 0.45 | 0.49 |
| 11 | 0.48 | 0.49 | 0.49 |
| 12 | 0.48 | 0.45 | 0.49 |
| 13 | 0.67 | 0.64 | 0.65 |
| 14 | 0.67 | 0.65 | 0.65 |
| 15 | 0.67 | 0.66 | 0.65 |
| 16 | 1.15 | 1.09 | 1.14 |
| 17 | 1.15 | 1.12 | 1.14 |
| 18 | 1.15 | 1.12 | 1.14 |
| 19 | 1.61 | 1.59 | 1.61 |
| 20 | 1.61 | 1.59 | 1.61 |
| 21 | 1.61 | 1.64 | 1.61 |
| 22 | 2.07 | 2.01 | 2.04 |
| 23 | 2.07 | 2.13 | 2.04 |
| 24 | 2.07 | 2.08 | 2.04 |
| 25 | 4.67 | 5.30 | 4.61 |
| 26 | 4.67 | 6.26 | 4.61 |
| 27 | 4.67 | 6.08 | 4.61 |

cc: R. Comes
R. Ferguson
P. Gauvin
B. Goodman
R. Greene
C. Lilly
J. Myracle
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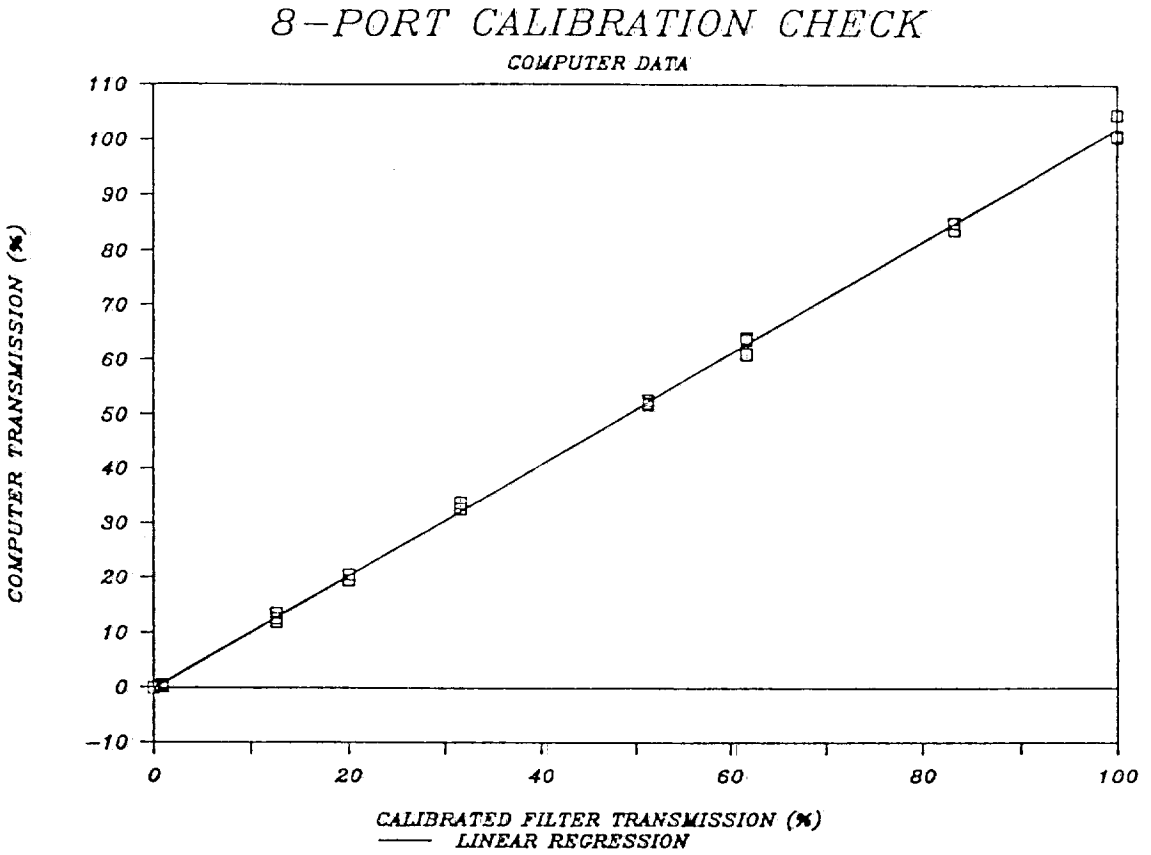


FIGURE 1. Plot of the computer determined transmission values as a function of the expected transmission values. Points: data, Line: linear regression.

Linear regression information:

| | |
|---|---|
| Intercept: | -0.23 |
| Slope: | 1.0228 |
| R squared: | 0.9992 |

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Source: https://www.industrydocuments.ucsf.edu/docs/rnkm0000

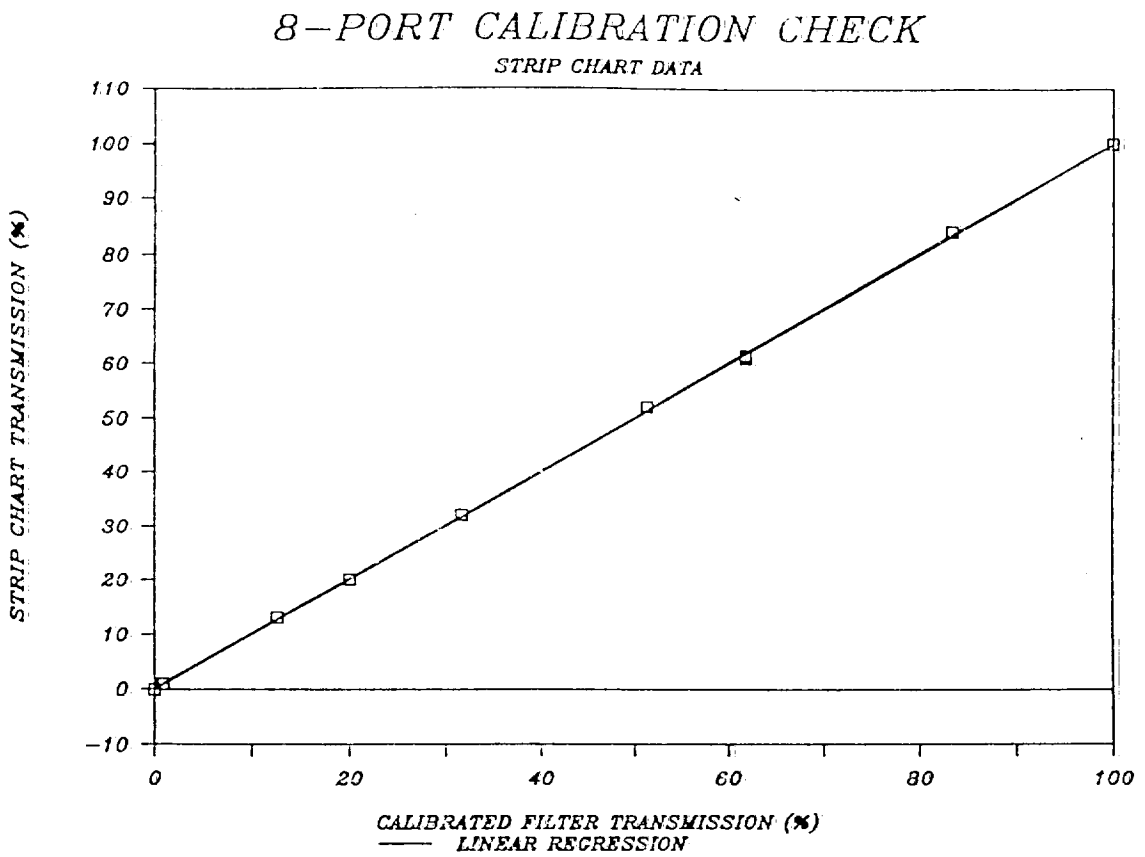


FIGURE 2. Plot of the strip chart transmission values as a function of the expected transmission values. Points: data, Line: linear regression.

Linear regression information:

| | |
|---|---|
| Intercept: | 0.16 |
| Slope: | 1.0015 |
| R squared: | 0.9999 |

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Source: https://www.industrydocuments.ucsf.edu/docs/rnkm0000

APPENDIX C

M E M O R A N D U M

TO: J.E. Wickham
Philip Morris USA

FROM: Boyd Fagan
U.S. Testing Co.

SUBJECT: Interim Summary Report of Phase I, Project #032717

DATE: May 30, 1989

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This summary report addresses the initial phase of testing as agreed upon in earlier discussions (ref: our memorandum report of project #032538), and as reviewed during our conference in Richmond on May 11, 1989.

A review of the data obtained through May 10 indicates that the measuring system appears to be functioning in accordance with its stated purpose, which is to make quantitative measurements directly proportional to the smoke produced by the static burning of cigarettes.

During the referenced conference, it was agreed to re-title several of the parameters in the data printout as follows:

1) "% Extinction" would be changed to "% Attenuation"
2) "SBT" (Static Burning Time) would be changed to "SBT, min."
3) R Conc would be re-titled "Extinction Coefficient"

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The means of expressing differences in the smoke produced was understood to be "X% less than" or "Y% greater than" the reference cigarette chosen. This would be done by plotting "Extinction Coefficient" vs "% smoke" with Marlboro Lights plotted as 100%.

An illustration of this is shown in Figure I attached, which also serves as an example of the efficacy of the proposed measuring system. Please note that this is a simple 2-point plot at zero and 100%. Determinated from this curve the average value of sample 9DBI is shown to be 25%. With only 2 values for ML8-BI, which represents a 50:50 mixture of 9DBI and ML8, the theoretical value would be 62.5% and the actual measured value from the curve is 65%, which is within the expected range of deviation.

The calibration data using the neutral density filters arrived too late to be incorporated into this memo, but is referred to as corollary to this report, and will be included in our final project report.

The final details of Phase II testing were also agreed upon.

Boyd Fagan

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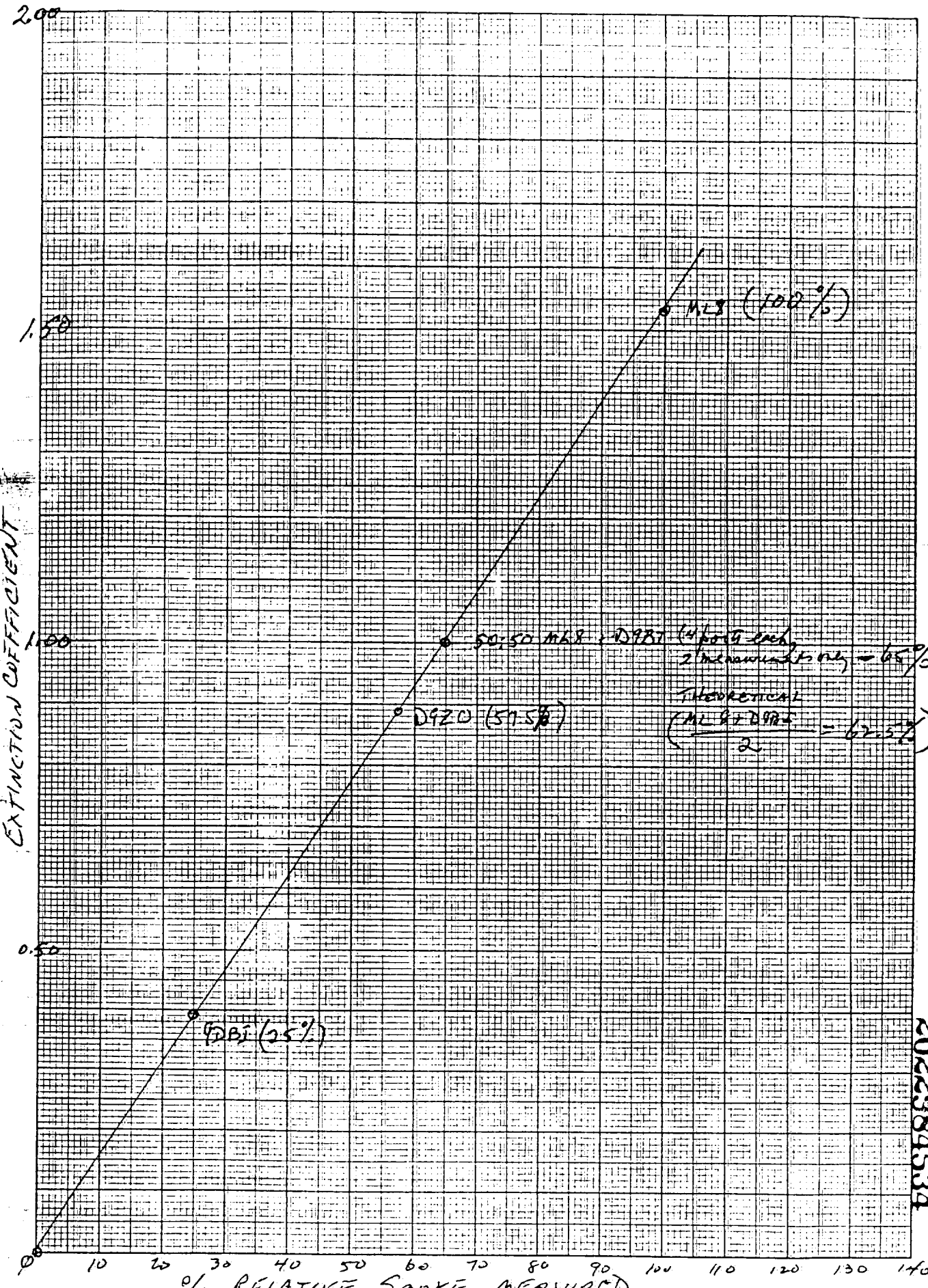
Source: https://www.industrydocuments.ucsf.edu/docs/rnkm0000




KEUFFEL & ESSER CO. 10 X 10 TO ½ INCH 7 X 10 INCHES MADE IN U.S.A.

Source: https://www.industrydocuments.ucsf.edu/docs/nkm0000

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APPENDIX D

MANUAL FOR THE 8-PORT SIDESTREAM MONITOR

START UP

**WARNING: THIS INSTRUMENT USES A CLASS II HeNe LASER. DO NOT STARE INTO THE LASER BEAM.**

Laser: PMS laser

The laser is turned on by the key switch on the laser power supply, the small black box on the left side of the monitor. The laser must be on for at least 1 hour before the monitor can be used, 1 1/2 hours is better. The laser can be left on over night if the instrument is going to be used first thing the next day.

Detector: Oriel Detection System Model 7072

The detector control box is located at the right side of the smoking machine. The various switches and knobs should be placed on the following settings:

45 Volts - off
Response - medium
Ambient Suppress - X $10^{-7}$
Zero Set - off
Multiplier - X $10^{-8}$

Turn on power switch.

Air Pumps:

Each pump has a line switch. Turn them on. Let them warm up for 10 minutes.

Smoking Machine: Filtrona 8-port

Turn on main power switch labelled 110 VOLTS.

The Cambridge pads should be inserted into the smoking ports. Due to the lack of space between the back of the hood and the smoking machine, this is a somewhat difficult task. Push the plastic port tubes back into the machine. Place a red rubber cigarette holder on each pad and press the pads onto the plastic port tubes. Pull each pad/port tube assembly out until the red rubber holders come through the holes in the hood. You may have to rotate the pads to align them with the holes.

Pen Recorder:

The pen recorder is located near the detector control box.

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The recorder is set to use the upper pen and the various controls should be set on:

Range - 50 mV
Upper Pen Switch - RECORD.
Chart Speed - 2 cm/min
Chart Drive - off

Turn on power switch.

Computer:

For more details, see the attached memo by R. Greene.

Turn on the computer using the red switch on the right side of the computer. Turn on the monitor by pulling the CONTRAST knob on the front. Turn on the printer using the switch on the right side.

Using the computer keyboard, type after the C:> prompt:

**cd nb (enter)** changes to "NB" directory, prompt should now be C:\NB>.
C:\NB>go Starts Labtech Notebook.

When "running" appears, type "**d**" to get back to DOS.

The screen should look similar to this:

**C:>cd nb (enter)**
**C:\NB>go (enter)**
running
**d**
NB* C:\NB>

CALIBRATION

Flow Rate Adjustment:

After the air pumps have warmed up, check and adjust the flow rates. The flow rates are checked using the rotameters on the two vertical support posts. Firmly holding the brass valve with the long narrow handle attached to the rotameter, turn the valve so that the air is pulled through the rotameter causing the steel ball in the rotameter to float. The middle of the ball should be at the 70 mark.* If it is not at 70 adjust the flow to 70 by turning the brass valve with the round handle. Once both rotameters read a flow rate of 70 turn the two narrow handled valves back so that the air is pulled through the hood. There should be no air passing through the rotameters now.

Check flow rate and adjust if necessary after every 5 runs.

Detector Adjustments for a Cold Start:

Once the laser has warmed up, the zero of the detector has to

*With only one rotometer the middle of the ball should be at the 65 mark.

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be checked.

1. Turn the Zero Set switch to "on." If the digital readout does not show "0.00," then adjust the knob above the switch to do so. Turn switch back to off. It is unlikely that you will have to make any adjustment.

2. Close the shutter. The meter should read "0.00". If it does not, adjust the ambient suppress knob. This knob has a lock to prevent inadvertent fiddling. The visibility monitor was designed to run with the room lights on. If the room lights are turned off or changed, the ambient suppress may need to be readjusted.

Detector Adjustments:

Before each run the detector has to be adjusted so that it reads 1.00 on the meter. This is done by rotating the small, fine adjustment knob labelled Multiplier. This is a touchy adjustment and requires a light touch.

Extra note: The meter reading may vary in the last digit due to a slight instability in the laser. Don't worry about it.

SET UP

Hood:

Flip up the sides and front of the hood until they catch on the magnetic holders. There is a small pin at the bottom of each of the sides that lock into holes in the hood front. Lift the sides first.

Cigarettes:

Cigarettes should be conditioned. Mark on at least one cigarette the positions 10mm and 40mm from the lighting end. These positions will be used to start and stop the data collection. Mark on all of the cigarettes the position 9mm from the filter end. Insert the 8 cigarettes into the holders up to the 9mm mark. Adjust the cigarettes so that they are all horizontal. Lift the lighting bar up to the cigarettes. By loosening the set screws on top of the lighting bar, position each lighter so that it is about 1-2mm from the end of the cigarette. THE LIGHTERS SHOULD NOT TOUCH THE CIGARETTES!

Chart recorder:

Change Chart Drive to CM/MIN.

Set Up for Data Collection on the Computer (from Randy Greene):

Collect the data on each smoking run using the program "visci"

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NB* C:\NB>visci (enter)
Follow the instructions on the computer screen.

The first step is to establish an open shutter calibration. The computer is set to only accept calibration values greater than 48 mV. If the calibration fails, make sure the detector reads 1.0 and try again.

RUNNING

CHECK:
- O Has the laser been on for 1 1/2 hour?
- O Has the flow rate been checked and adjusted?
- O Has the detector been adjusted?
- O Are the cigarettes and lighting bar ready?
- O Is the chart recorder ready?
- O Is the computer ready?

Computer:

The computer will ask for information on the cigarette sample to be run such as code, burn length, etc. Type in the information or accept the default values shown in parentheses by hitting the enter key.

The computer will then ask for a closed shutter calibration point. Follow the screen instructions. If the computer says this value is too high, make sure that you closed the shutter as requested.

The computer will now ask for another open shutter calibration. If the computer says this value is too low, try the calibration again. If it fails a second time, check to see if the detector reads close to 1.000, adjust if necessary and try again.

The computer will then show instructions for lighting the cigarette and beginning and ending the smoking run (see below).

Lighting:

Turn the green toggle switch up to AUTO.
Press down the red toggle switch to IGNITER START until the lighters become red hot.
Quickly, turn the green toggle switch to TEST and back to AUTO. The machine will now take a puff, lighting the cigarettes.
Release the red switch.
Turn the green switch back to MAN. Otherwise, the machine will take another puff in one minute.
Close the front and sides of the hood making sure the sides are locked into the front.

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Data Collection:

When the char line reaches the first mark on the cigarette, press the "ENTER" key to begin data collection. The computer should display "RECORDING IN PROGRESS...."

When the second mark is reached by the char line, press any key to stop the run.

Getting the data:

After each run, use the "Print Screen" key to print the results. The results are also stored in an RS/1 compatible file named CISUM.DAT. See attached memo by R. Greene for details on how to read this file.

The computer will then ask if you wish to make another run. Typing **y (enter)** will start another run. Typing **n (enter)** will end the program and return you to the NB* C:\NB> prompt. Remove the cigarettes and prepare for the next run.

Ending the Program:

Type **n (enter)** when asked.

SHUT DOWN

O Remember to print the results after each run!

Turn off all equipment, except the laser. If the 8-port monitor is to be used first thing the next day, leave the laser on. Otherwise, turn the laser off, too. Do not leave the pumps running.

MAINTENANCE

Optical System:

The optical system (laser, mirrors, hood and detector) needs to be kept in alignment. In addition, the windows in the hood that the laser beam passes through need to be replaced at regular intervals.

To replace the windows: Do this once a week when monitor is heavily used. Change the windows before turning on the laser on Monday morning after a weekend shutdown. Loosen the screw knobs holding the mirror support posts and pull out the mirror mount and attached post. Loosen the two screws on the laser carrier that clamp the carrier to the horizontal rail. Move the laser back from the hood about 2 inches. With a knife remove the four square glass windows from the round black apertures on the hood. The windows are held on with rubber cement and should come off easily.

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**The windows are thin glass and break easy. Be careful not to cut yourself with the glass.**

Take new windows from the box of microscope cover slips and put a small amount of rubber cement in two corners. Then, place the windows on the black apertures being careful not to get fingerprints on the surfaces. Move the laser back close to the hood and tighten the clamping screws on the carrier. Make sure the laser carrier is not loose in any way. Place the mirrors into the post holders so that the mirrors and the aperture holes roughly line up. Turn on the laser. Rotate the right mirror until the laser beam is reflected into the center of the left mirror, then tighten the screw knob. Rotate the left mirror until the laser beam is reflected through the lower right aperture into the detector.

To align the optical system: During this procedure you will be adjusting the laser beam to get the largest possible reading on the detector. Let the laser warm up for 1 hour. The detector should be showing some number greater than 0 when the mirrors were put back in and roughly aligned after replacing the windows. Each mirror has two small screw adjustments on the back. Starting with either adjustment on the right mirror, slowly turn the screw back and forth and watch the detector. Turn the screw to get the largest number on the detector. Go to the other screw and turn it to get the largest number on the detector. Now with the left mirror repeat the process. Return to the right mirror and repeat. Finally, repeat the process a second time with the left mirror. These last two steps should require only minor adjustments. The final reading on the detector should be higher than the reading taken before replacing the windows.

Pumps:

The pumps and the air handling system need regular maintenance. Every day check the level of oil in the glass oil jars on the side of each pump. Put in oil if the oil level is below the line. Every two weeks replace the glass wool filter material in the plastic tubes on the pumps. To do this, unscrew the tops of the tubes and pull out the dirty glass wool with forceps.

**Wear gloves!**

Repack the tubes with clean glass wool. Do not pack too tightly. Also, replace the inlet filters on the pumps. These filters are in the metal jars attached to the pump inlet.

D. McRae March, 1989

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